PROBLEMS OF WASTE DISPOSAL IN THE ARCTIC ENVIRONMENT

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For Presentation at the 1971 Annual Meeting of the
Air Pollution Control Association
Pacific Northwest International Section
Calgary, Alberta
November 21-23, 1971

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DEFINITION OF PERMAFROST

Permafrost, or perennially frozen ground, is defined exclusively on the basis of temperature and refers to the thermal condition of earth materials such as soil and rock when their temperature remains below 32°F continuously for a number of years. Permafrost includes ground which freezes in one winter, remains frozen through the following summer and into the next winter. This is the minimum limit for the duration of permafrost; it may be only a few inches thick. At the other end of the scale, permafrost may be thousands of years old and hundreds of feet thick. The mode of formation of such old and thick permafrost is identical to that of permafrost only recently developed.

Even a small negative heat imbalance each year results in a thin layer being added annually to the permafrost. This annually repeated process can produce a layer of permafrost hundreds of feet thick after several thousands of years. This process does not cause the permafrost to increase in thickness indefinitely but a quasi-equilibrium is reached whereby the downward penetration of frozen ground is balanced by the flow of heat from the unfrozen ground below. Permafrost is not "permanently" frozen. Changes in climate and terrain can cause the permafrost to thaw and disappear.

Permafrost in Canada
Map 1246 A
Geological Survey of Canada
Dep't of Energy, Mines and
Resources.

PROBLEMS OF WASTE DISPOSAL IN THE ARCTIC ENVIRONMENT

INTRODUCTION

This paper deals with some of the current waste disposal problems in the western Canadian Arctic, and more particularly at points along the Mackenzie River and its delta area on the Arctic Ocean.

The political boundaries of the Yukon and Northwest Territories contain all of the Canadian Arctic. This area of 1½ million square miles, of which 53,000 is fresh water, contains a total population of some 50,000 people, chiefly inhabiting the southern latitudes.

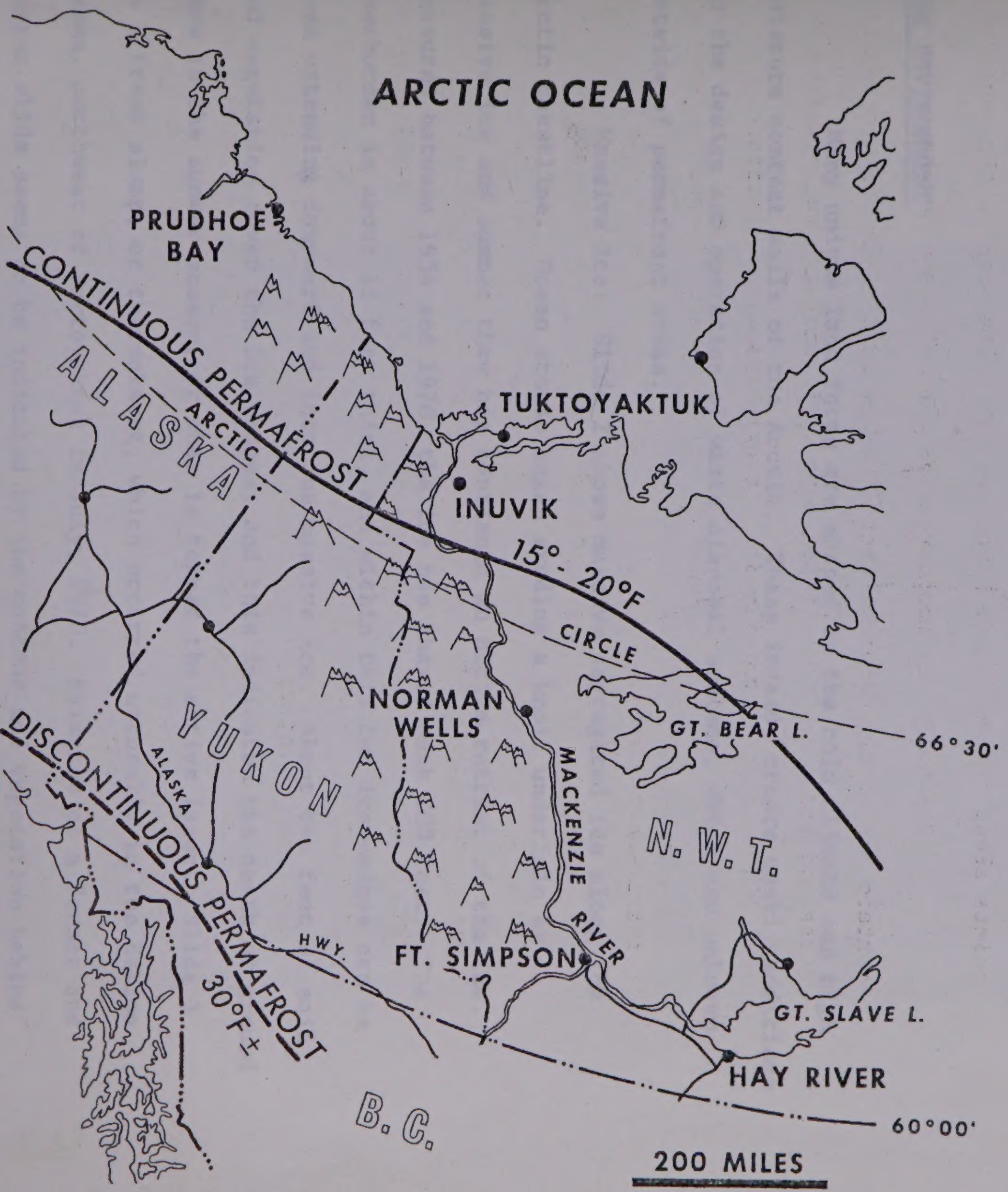
Why then, do we speak of waste problems in such an enormous, sparsely-populated land?

Many answers can be found. Ecologists and conservationists describe the north as one of the world's last true wilderness areas. Governments, already facing difficult pollution problems, have begun strong protective legislation to ensure protection of all the environment for the future. Industry for its part, realizes more than ever that environmental protection must be built into its operational planning; while the environment itself, with its cold climate and permafrost, causes decay to be slow which is beneficial in many ways, but not where wastes are concerned.

MAP

The attached map locates the various points of reference. A solid line shows the boundary between the continuous and discontinuous

WESTERN CANADA ARCTIC

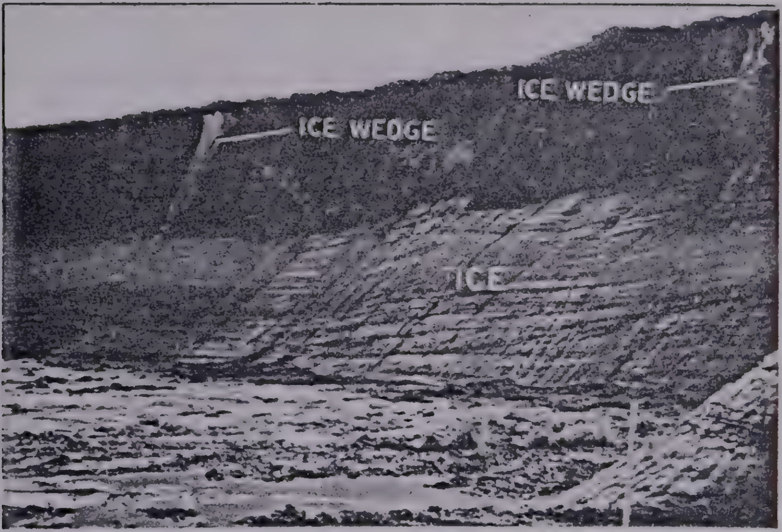


permafrost zones. The mean annual temperatures of 15°F and 20°F indicate that this boundary is generally between these two isotherms. Likewise the dashed southern limit of discontinuous permafrost is mainly just below the 30°F isotherm.

THE ENVIRONMENT

Many unique land forms are shaped by the cold climate and high moisture content soils of the Arctic. These indeed, create costly additions to the design and operation of waste disposal systems, which are unknown outside of permafrost areas.

Massive Ice: Slide 2 shows massive segregated ice along the Arctic coastline. Ocean storms began eroding a knoll underlain by massive ice and summer thaw has continued an active retreat of the ice. Measured between 1954 and 1970, the ice has thawed back 200 feet. The overburden is about 15 feet thick, and within this two ice wedges can be seen extending downward and into the massive ice. About two feet of soil and vegetation cover the ice wedges, and this indicates the depth of ground thaw in the summer season, or what is termed the active layer. Slide 3 is a fresh slump, or thermokarst, which occurred naturally in the Eskimo Lakes, northwest of Tuktoyaktuk in July, 1970. Evidence of a former and larger slide seems to be indicated by the contour and vegetation behind the present feature. One can readily visualize what would happen to sewer lines, heated or cold oil lines, or even a structure on pilings located in this vicinity.



SLIDE 2.   MASSIVE SEGREGATED ICE.

SLIDE 3.   A SLUMP (THERMOKARST) WHICH HAS OCCURRED NATURALLY.

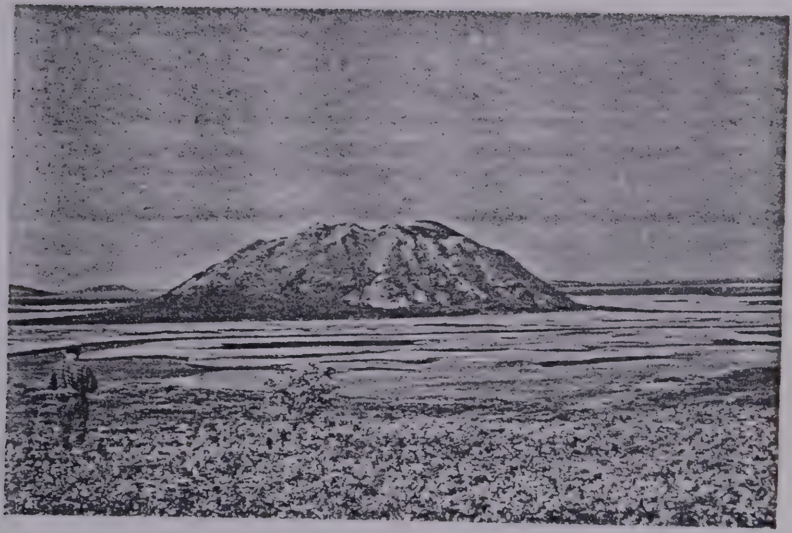
Massive ice is very extensive throughout permafrost areas, and very difficult to predict. One occurrance has recently been reported in the discontinuous permafrost zone, 20 miles north of Fort Simpson along the Mackenzie River.

Slide 4 is the Ibyuk pingo, an intrusive ice feature, standing some 135 feet above the low surrounding terrain. There are over 1400 pingos of various sizes located in and surrounding the Tuktoyaktuk peninsula. Their formation is due to drainage or infill of lakes and streams which allows permafrost to aggrade, form a closed system, and gradually thrust the ice core pingo up through the weakest point. Thousands of years are required for development of a pingo. Water bodies deeper than the annual ice thickness do not have permafrost immediately below their bottoms.

Ice wedge polygons are another Arctic feature. Slide 5 shows a surface view of a series of low-centre polygons. Surface cracking in winter follows the same yearly pattern, and gradually an ice wedge enlarges through infill of the crack to raise edges and form polygons. The ice wedge thaws only to the base of the active layer which, with peat and moss cover, may only be a few inches below surface.

The wet centres of these polygons are inhabited by sedges, the summer forage for caribou and reindeer, while the drier edges sustain a community of dwarf birch, Labrador tea, cranberry, lichen and other plants. The low centres gradually infill with peat and become dry, high-centre polygons which small rodents like to inhabit. It takes approximately a thousand years to form between six-tenths to a foot of peat.

Slide 6: Denuded frost mounds, following a fire in August, 1968, show the natural surface roughness to be found in tundra and taiga areas.



SLIDE 4. A PINGO -- THE IBYUK NEAR TUKTOYAKTUK.

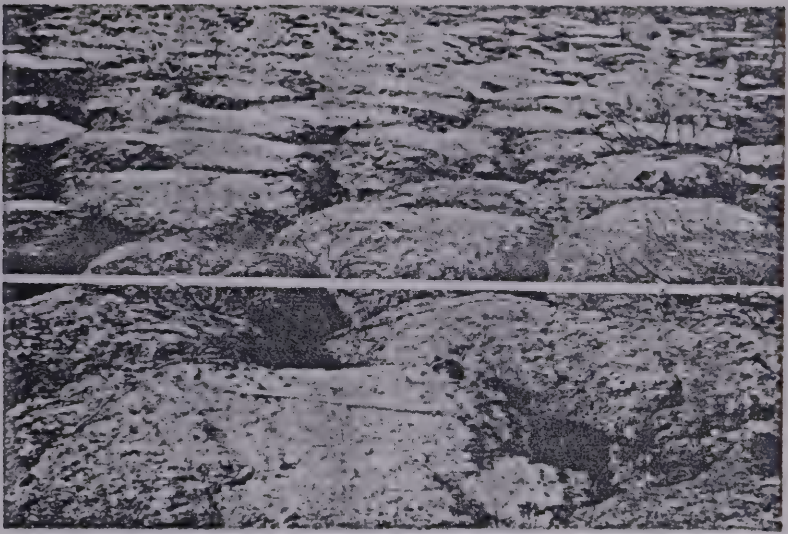
SLIDE 5. LOW-CENTRE ICE WEDGE POLYGONS.

Mosses and sedges originally inhabited the wedges where ice could be encountered several inches below their roots. The vegetated top of the mound thawed about two feet at the latitude of Inuvik, causing a dish-shape configuration to the base of the active layer. Following the fire, the active layer in the mound increased to four feet.

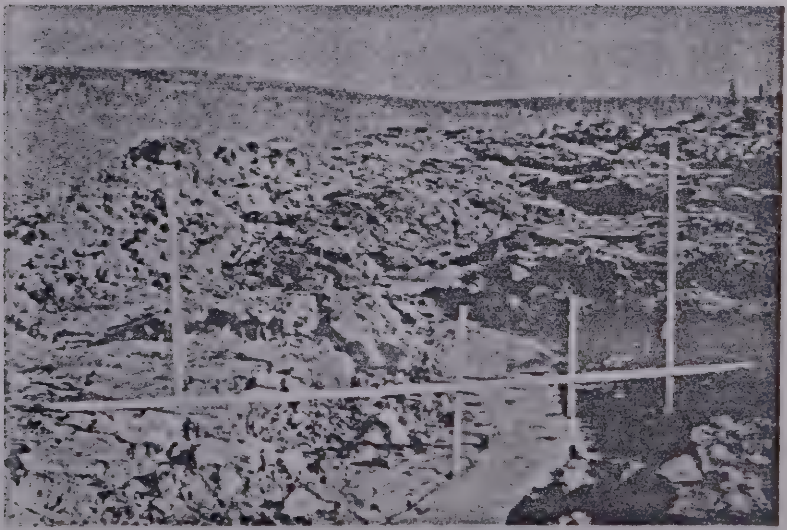
Slide 7 shows a bulldozed fireguard line 30 days after the vegetation and unfrozen surface had been stripped off. No rain had fallen, but as a result of thaw in high ice content permafrost soils, the gulley some 2 feet wide and 18 inches deep formed in this short time. This happened in 1968 also, and the area has still not stabilized.

All soils are not high in ice content however, and Slide 8 shows an excellent source of dry esker gravel which was being trucked 27 miles down the Mackenzie River ice in March, for a summer drilling rig site on a low silt area. A bulldozer and loader move the material as easily as they would in southern climates. River beds and other glacial features also supply excellent sources of gravel, but removal must be ecologically suitable.

The seasons are not entirely cold and indeed the short summer consists of 24 hours of daylight and often hot days in the 70° to 80° range with its accompanying swarms of black flies and mosquitoes. Annual precipitation may total from 6 to 10 inches and this, by all southern standards, makes it a desert, except for permafrost. Inuvik for instance, has roughly 10 inches of precipitation made up of 60 inches of snowfall which reduces to 6 of precipitation and 4 inches of precipitation in the form of rainfall during the summer.



SLIDE 6. FROST MOUNDS WITH VEGETATION BURNED OFF.



SLIDE 7. THERMAL EROSION IN FIREGUARD -- 30 DAYS AFTER FIRE.

Vegetation starts growth in the long hours of daylight directly after spring runoff. But, because of lack of rain thereafter, the plants depend on thaw in the permafrost (active layer) to sustain them for the remainder of the season. Marsh-type plants are an exception, of course.

Slide 9 shows tundra vegetation on the Tuktoyaktuk peninsula in spring. Shallow thermokarst lakes are very evident, and these are due to pore ice thaw in sandy permafrost. Permafrost does not allow subsurface migration of water between the lakes and equilibrium is maintained by their inlet and outlets.

WASTE DISPOSAL

Waste disposal methods in the Arctic environment create many problems that are not found in southern climates. A discussion follows of various methods currently used at oil rig sites, seismograph camps and solid wastes at the Norman Wells refinery. Other problems are mentioned, and some domestic services are briefly commented on.

WASTE DISPOSAL AT OIL RIG SITES

Three types of waste occur at drilling sites -- drilling fluids, solid waste and camp wastes. Drilling wastes find their way into a large sump excavated out of the permafrost just beside the rig, while camp wastes empty into a smaller pit near the buildings. To dig these pits in winter, a pattern of holes are drilled and dynamite used to shatter the area. A large bulldozer with hydraulic ripper makes little

SLIDE 8. ESKER GRAVEL SOURCE IN THE MACKENZIE DELTA.

SLIDE 9. THERMOKARST LAKES ON THE TUKTOYAKTUK PENINSULA.

impression in the solidly-frozen ground, but has little difficulty with cleanout after blasting.

In southern climates, drilling muds are taken from the sump, spread and dried on the lease and returned to the pit for burial. This can hardly be done in the Arctic. Wastes freeze in the sump in winter, and it is impractical to consider the use of heavy equipment on the tundra in summer unless, of course, the well is a producer in which case gravel pads and roads must be built. Winter exploratory locations usually involve setting the rig directly on the frozen tundra.

The current solution to the drilling waste problem, therefore, is to mound over the frozen liquid and solid waste in winter with the excavated soils and perform minor hand cleanup in the summer. After settlement, the excavated soil will become the active layer, the wastes will remain solidly frozen, and surface revegetation will gradually take place.

Slide 10 shows a rig location, under preparation in March for summer drilling on low-lying delta silts. Pilings are set for the rig and camp, gravel pads provide access, and material storage is on platforms. Small pits will receive wastes and the fluids will be pumped under careful control into the channel. The whole area is liable to flooding in the event of a severe ocean storm, bird sanctuaries are adjacent, eskimo whaling takes place a short distance away in the ocean, and therefore pollution by any waste must be avoided. Garbage is burned in an oil-fired incinerator, and only charred cans enter the kitchen pit.

WASTE DISPOSAL FROM SEISMOGRAPH OPERATIONS

The nomadic nature of seismograph exploration requires that crews locate only a few days in one spot and move on. Waste is never great, but it can become accumulative over the years.

Camps are located at least 200 feet from any lake or stream when on land, and kitchen and wash house wastes are drained onto the ground. Snow, wind and frost quickly dilute the effluent.

Solid wastes, however, are more of a problem. This past year, oil-fired incinerators were added to each camp and results in the reduction of disposal problems were excellent. Only tin cans and scrap metal remain to be disposed, which is done by drilling 12-inch holes with a special bit for the shot hole rigs and simply dumping the solids in and covering the top of the hole with two feet of soil. Motors and large scrap naturally will not fit, so they are taken away for proper disposal.

Slide 11 shows a seismograph camp of 15 trailers plus fuel supply sleds and garbage burners pulled into place on one of the streams in the Mackenzie Delta. Special permission was given to let effluent drain on the channel ice, since the next stop for this waste was the ocean. Lakes in the delta could not be used for camp-sites however, and incinerated garbage was buried above the banks.

Slide 12 is one of the sled-mounted garbage burners in operation, with a stack of bagged waste ready for consumption. Five burners were ordered for last winter's operation at a price of approximately $4,500 each.

SLIDE 10. RIG SITE PREPARATION FOR SUMMER DRILLING.

SLIDE 11. A SEISMOGRAPH CAMP.

The central mounting of the burner was intended to give the least amount of jarring to its reinforced refractory lining during moves. An inspection of these linings after one season has shown only a few minor repairs to be necessary and all the present units, plus a number of new ones on drilling rigs, will be in operation this coming season.

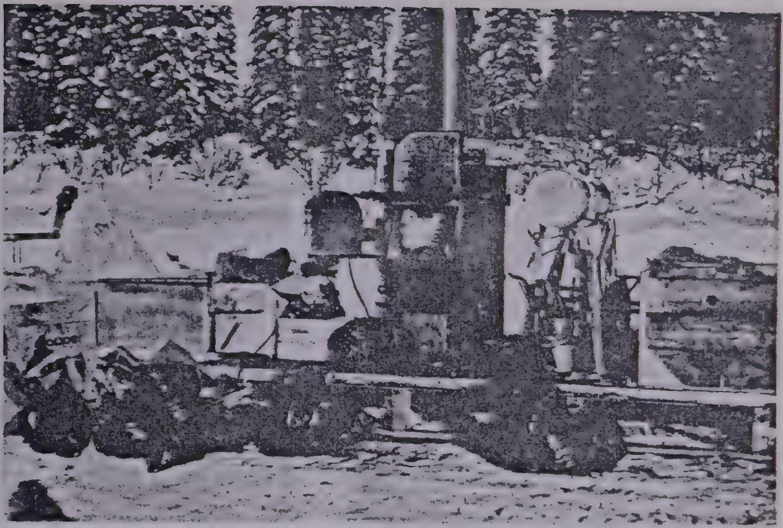
It has been gratifying to see how neat campsites can be with the addition of proper means of disposal.

Slide 13 is a censored documentation of just how some sites can appear on the tundra in summer. Hundreds of such sites would be an eyesore, and would create a tremendous disposal problem. This site is known to have been cleaned. In our area, 41 winter seismograph campsites were checked in summer by helicopter, and men and gear were airlifted to sites that required cleanup. The cost was high, but was necessary for environmental neatness. Incinerators have eliminated this problem.

SOLID WASTES

Barrels and metallic junk have been piled in scattered locations throughout the Arctic for decades; too costly to move and still too early for the ecosystem to dictate that recycling is necessary.

At Norman Wells, worn out machinery, a mountain of rusty fuel drums and junk had been accumulating since the Canol Project of World War II days. The decision was made a year ago to remedy the situation.



SLIDE 12. A SEISMOGRAPH CAMP INCINERATOR IN OPERATION.

SLIDE 13. WINTER GARBAGE VIEWED ON THE TUNDRA IN SUMMER.

This material would have instant value if near a salvage market, but with 590 miles of river and 725 miles of rail transport, its ultimate dollar value was nil. The solution, then, was to bury the junk. Large trenches were dug and old machinery and scrap was pushed in and covered over. But the drums created a problem. A crusher was fabricated and began its labours of flattening some 65,000 drums in mid-March. Satellite dumps turned up throughout the woods, but now all have been disposed of and only the seasonal discards remain for disposal.

The drum crusher at Norman Wells, Slide 14, shows flattened drums piled in the pit ready for burial. The total cost of the unit is about $25,000 and an average of 500 drums a day can be flattened. The unit is portable, and could well find application in other waste disposal campaigns.

Slide 15 shows an abandoned site of rusty drums, twisted iron and other junk on the Arctic Ocean front, where someday, cleanup will be necessary.

DOMESTIC SERVICES

Many northern communities are now benefiting from the advantages of piped water and indoor flush toilets. Other communities have seen and want the same services.

The systems, for obvious reasons, cannot be buried in most permafrost areas, for they would certainly either freeze up or collapse if their heat melted the permafrost. The solution in the north has

SLIDE 14. THE DRUM CRUSHER AT NORMAN WELLS REFINERY.

SLIDE 15. DRUMS PLUS OTHER JUNK AT A SITE ON THE ARCTIC COAST.

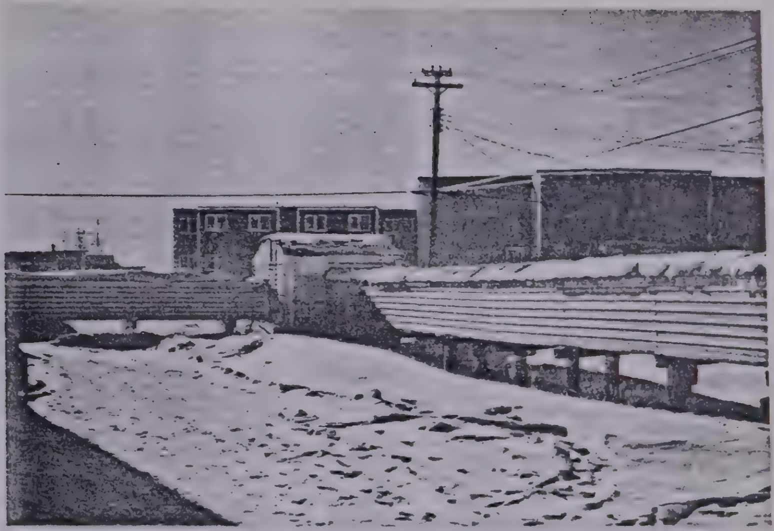
been the use of utilidors which are weatherproof box structures containing the piping within an insulated interior, that sit above ground on piling, berms, logs, or even old fuel drums. Most systems have circulating heat lines to keep the water and sewer line from freezing.

At Inuvik, Slide 16, the original system carried water and sewer lines plus a super hot water line at 350°F to provide heat for the buildings as well as the utilidor. The system has functioned well for 10 years, with a few problems; however, the initial cost was high, somewhere between $200 and $230(1) per foot and it is felt that future lines should not carry the heating water unless large buildings are involved.

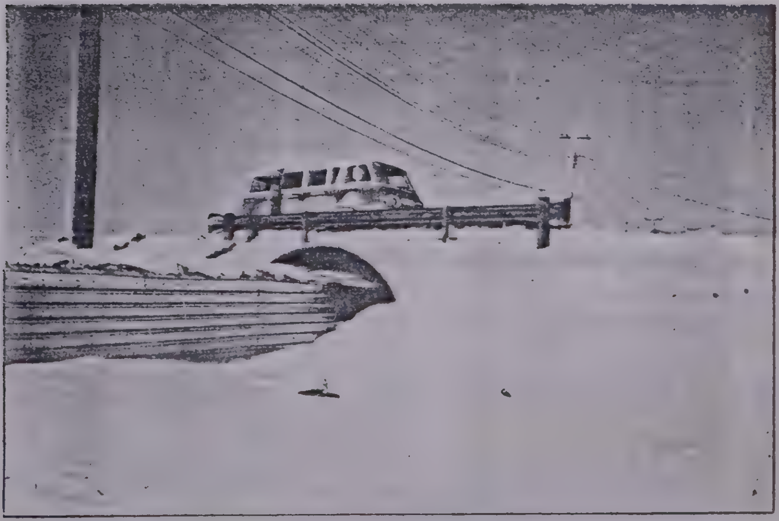
These utilidors contain asbestos-cement pipes used for sewer and water lines, and insulated welded steel pipes to supply the super-heated water to the buildings. The heating pipes had to be placed above the water and sewer pipes, due to service connections, and this has led to heat stratification within the utilidor. In some cases, radiation therefore did not provide enough heat to keep lower pipes from freezing, and insulation had to be removed from the heat line.

The conduits are large enough for easy repair access, which had necessitated some costly road overpasses shown in Slide 17.

Sewage treatment in the north is usually primary with ponds or backwaters used for holding areas which receive their flush-out with spring runoff and flood waters. Inuvik has such a system which flushes into one of the delta channels each spring.



SLIDE 16. INUVIK UTILIDOR SYSTEM.



SLIDE 17. UTILIDOR WITH ROAD OVERPASS.

Some settlements without water and sewerage present a difficult and very costly challenge for designing sanitary facilities. Slide 18 shows a small settlement on the Arctic Ocean which has a population of 130 with 34 attending school. Crowding is not necessary, so each family seems to have his own knoll along the ocean front. When considering service connections, it would be debatable whether to move the houses to the utilidor system or take the utilidor to the houses; a point which stresses the value in townsite planning.

The disposal grounds for this settlement are on the ocean ice, and in Slide 19 we see plastic bags of sewage, boxes, cans, barrels and all forms of waste awaiting spring breakup, to carry the ice far out to sea where its cargo is discharged. Sometimes, however, unfavorable winds pile it unpleasantly back on shore.

FUTURE TRENDS FOR WASTE DISPOSAL

As the tempo of industrial activity increases in the Arctic, the problems of waste disposal and environmental protection multiply.

Disposal of heavy metallic wastes has been started in a small way, but other solutions will have to be found. Perhaps recycling will be the answer.

Garbage burners accompanying some exploratory oil operations have proven very effective, and it is obvious their use should increase.

Pits and primary treatment of domestic waste satisfy the exploration phase of the oil industry, but the development phase will

SLIDE 18. A SETTLEMENT ON THE ARCTIC OCEAN.

SLIDE 19. GARBAGE DUMP ON THE OCEAN ICE.

require complete treatment of waste. Some use is being made of propane-fired incinerator toilets, oil-fired plants are designed to boil off liquids and completely incinerate sanitary wastes, or pasteurize kitchen sink waters, while activated sludge sewage treatment plants capable of transport by Hercules aircraft are now a market item. The cost and transport of fuel oils for plant operation and the exploratory nature of present oil activity has not manifested the demand for this stationary type equipment. But, producing installations and large construction camps will automatically require complete systems of waste disposal when the production stage is reached. Reduced transportation costs for fuel could also be an enticement for small Arctic settlements to install disposal systems to eliminate current unsanitary dumping practices.

When Prudhoe Bay style oil reserves are found in the Canadian north, the influx of people will be great and the demand for good water systems, sewer services, and proper solid waste disposal will be instantaneous. It is our responsibility to see that these demands are met. It is equally our responsibility to see that in meeting them, we continue to safeguard the environment of the living Arctic.

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